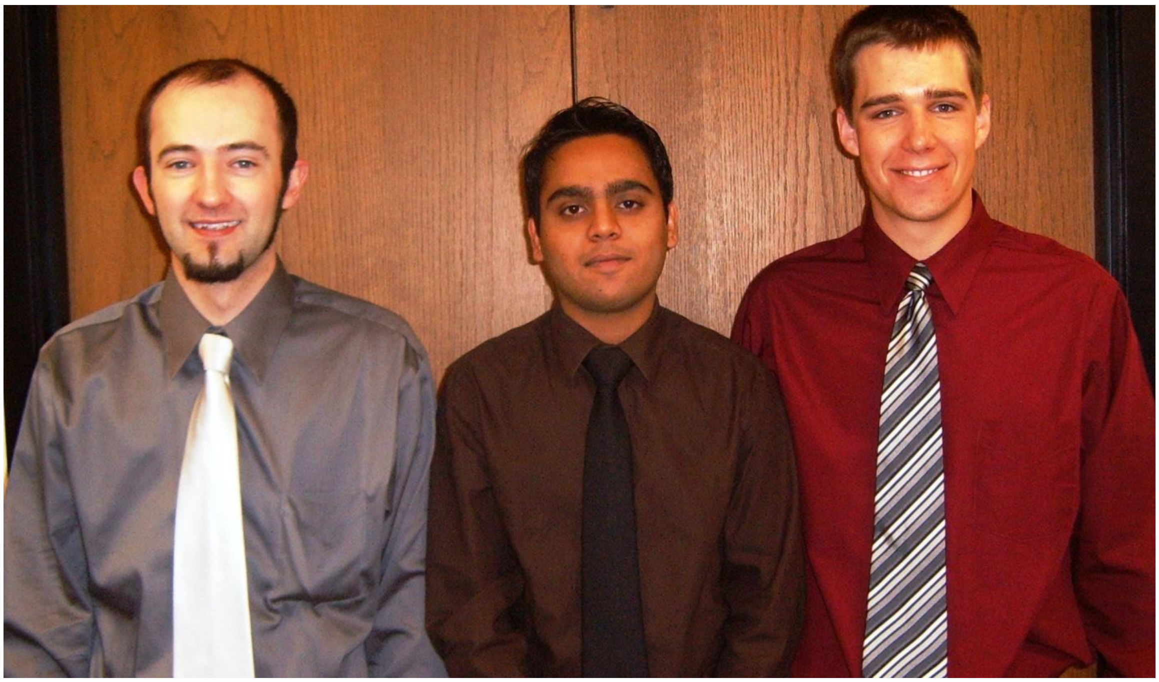
ENERGY HARVESTING

SD0716

Final Report



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Background

Our initial aim was to determine whether enough energy can be harvested from an overhead distribution line to power up a transmitter or other signaling devices like a LED array. However, working with high voltage transmission line has always been a tough task especially because of its hazardous nature. We cannot just build up our circuit and test it on the HV lines in the lab.

Our first step towards the project was to carry out calculations to find out how much energy could be harvested given the distance (between the line and the sensor), line loading, transmission characteristics and sensor dimension. The result was very low and below what was required to run a signaling device such as a transceiver. So we decided to walk on parallel tracks to achieve our goal.

We planned to build a highly efficient and reliable sensing apparatus that detects the energized high voltage line by detecting the presence of E-field. Initially the device is powered by a battery, and with enough time we plan on replacing this with an electrical storage device that we could be working on along the way.

By initially using a battery, we were capable of adding features to our project like transceivers to transmit data from pole to pole. This communication would make it possible to determine which line has been tripped offline. Our network consists of a central point or transceiver that is labeled as a router and we are capable of adding and endless amount of routers from other poles with one as a coordinator. This allows us to have a handheld device that can link up to the router on a pole and be able to tell us if any of the lines have been tripped that are linked to this substation transceiver.

Initial Design Requirements

We are required to build a device that meets the following requirements:

- The apparatus must detect energized High Voltage line by detecting the presence of the E-field which is induced around the wire when it has a potential on it
- The apparatus must work even when the line loading is very low or has little to no current and it should also work irrespective of the distribution model used
- The apparatus must withstand the diverse characteristic of the weather conditions and it must be able to work in windy, rainy, and snowy conditions. These climatic conditions must not affect the readings from the sensor.
- The apparatus must be able to send all the information sensed by the sensor to the data receiving location at high accuracy and very efficiently. The distance of the data transmission must be large enough to transmit pole-to-pole

- The apparatus would be consisting of various components like,
  - (I) Sensor (a metal plate/wire)
  - (II) MOSFET (Switch which would turn ON when the line is active)
  - (III) Diodes (For MOSFET protection)
  - (IV) Transmitters (For sending/receiving data)
  - (V) Misc. components like LEDs, resistors, potentiometers etc.

  These components must be very efficient and consume very small amount of power, so that our device is good enough to work with the minimum power available to us.
- The apparatus can be powered by a power supply most likely a solar panel or battery initially or until we develop an electrical storage circuit

Field Testing

So by the end of our first semester we had a sensing apparatus which detected the E-field around a standard extension cable illuminating an LED. We also had a working field testing circuit to hand off to Moorhead Public Service to test near live power lines.

Moorhead Public Service field tested our original sensing circuit on live power lines. We originally placed an LED rather than the transceiver we had planned on, just for ease of use while the lineman had the circuit. We had planned on seeing the LED 'ON' when it was within 36" of both 12.5 and 7.2 kV lines given results from the 110V line in the lab. The following chart summarizes the results:

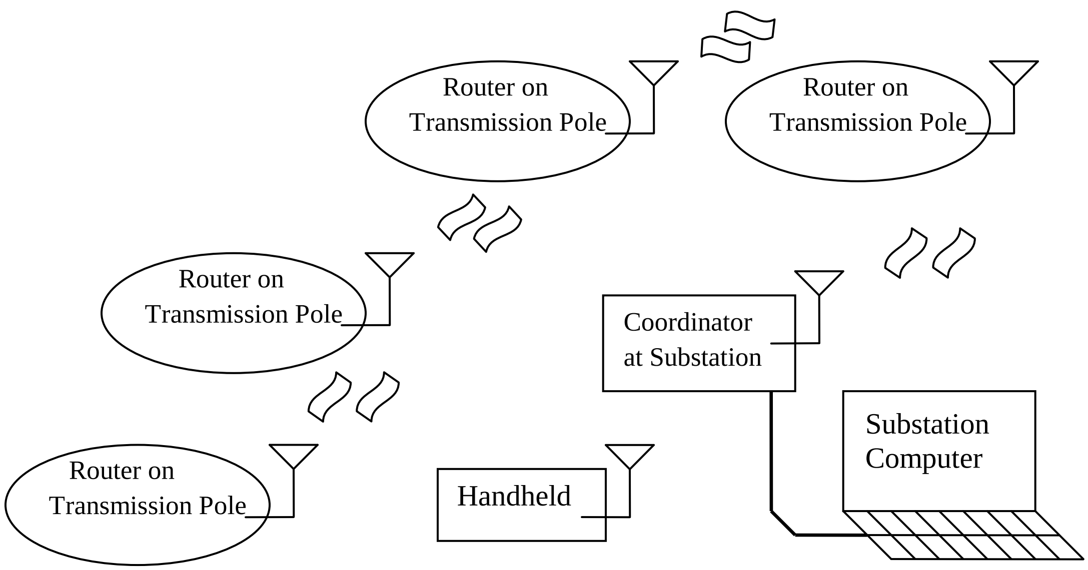
Conductor Specs	Voltage	**Distance to Sensor for Steady LED 'ON'**
447ACSR 3-Pahse	12.47kV	46"
477ACSR 3-Phase	12.47kV	66"
#1ACSR 1-Phase	7.2kV	96"
477ACSR 3-Phase	115kV	360"

Upon viewing these results we noticed that the 30 foot distance they got from the 115kV line was way beyond what we expected to see. After consulting them and reviewing the location, we came up with the explanation that there was existing underground circuitry in the area which could have thrown our results off. Another idea we came up with when we returned to campus and found the MOSFET to be blown and that led us to believe the sensor could have been too sensitive for the field in the area around the 115kV.

Final Circuit Designs

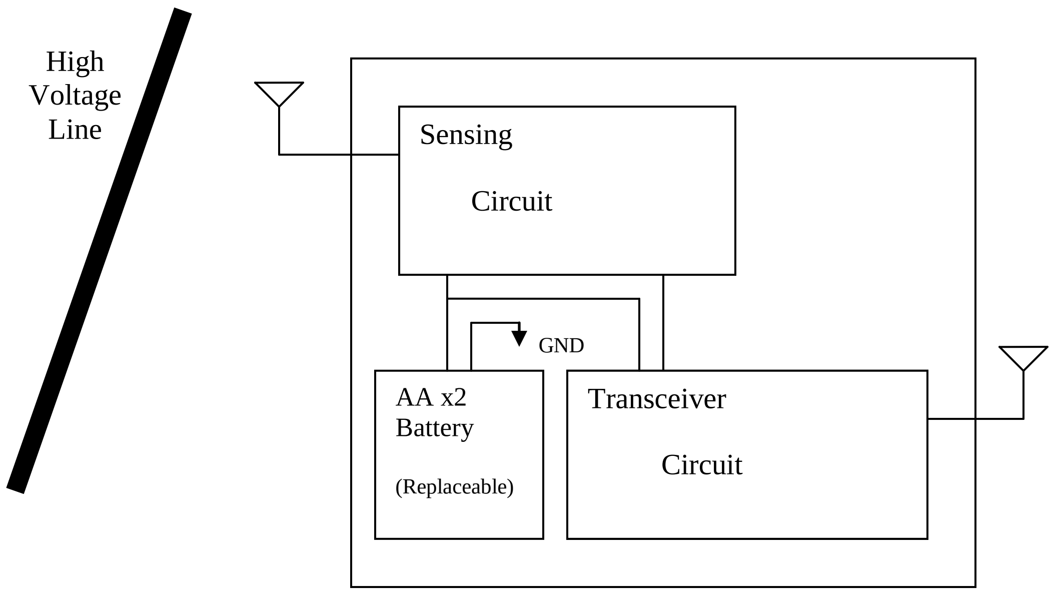
Now that we knew our design should work in the field, our communication grid was something we had to decide upon before we could settle on a specific transceiver. We decided on a first choice, DP1203-C868 made by Semtech. We first thought that we could implement these without a processor and maybe use another IC chip like a simple timer or other simple control. After closer investigation we found that a processor would be necessary so we continued our search for the perfect transceiver. After looking at many other models online, we decided to work with the XBee model XB24-BSIT-004 by Zigbee of Digi-International. This happened to work out very nicely for us since another design group already had the development kit for this model of transceiver and the device had many added features we could potentially use.

Communication Grid

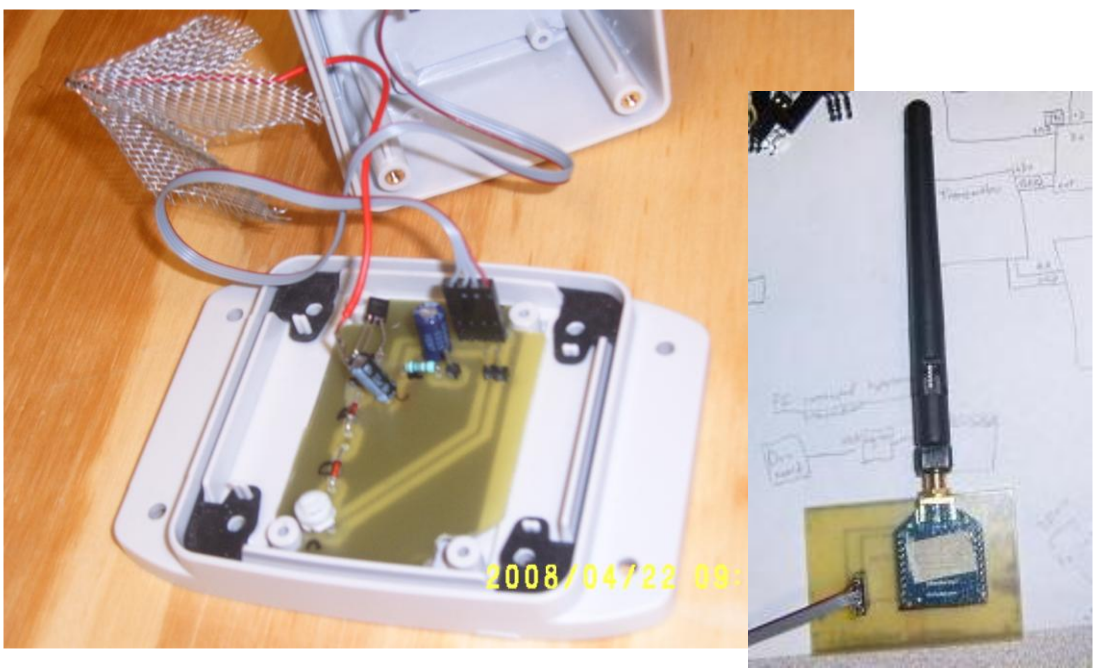


Once we had a transceiver picked out and working on a breadboard, it was time to attempt implementing it with the sensor circuit as it would work in the field. This transceiver turned out to be an excellent pick since we were able to use an A/D converter included on the chip. This enabled us to keep the sensing enclosure relatively simple and not use a processor or any other advanced chip.

Sensor Unit



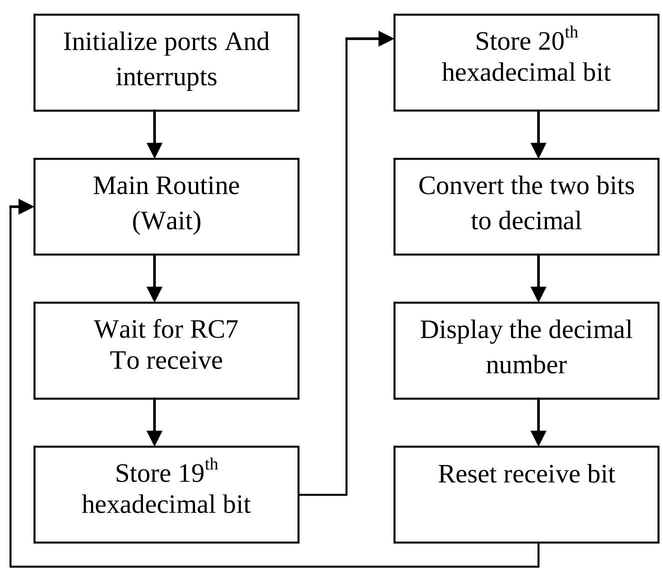
*Note: Actual circuit diagram attached on page 9



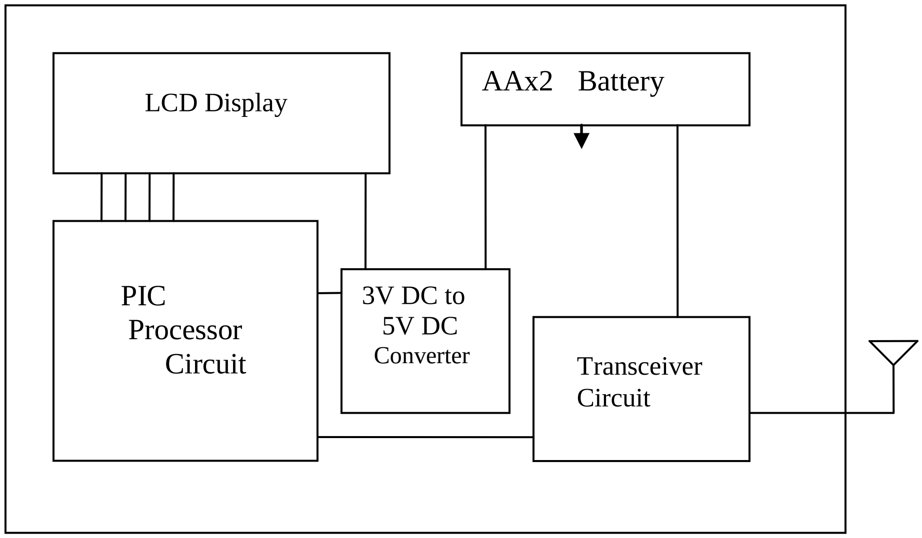
Now that we had the initial design close to completion, it was time to focus on adding a handheld option or continue researching and developing energy harvesting. Since we were using 3 volt transceivers, we did not have a replicated e-field of a common distribution line readily available, and time was running out we focused on the handheld.

This was going to use common components to this department including the PIC16F876 processor and the 4x20 LCD display used in the embedded class. Since these two main components worked from 5 V DC, we had to include a DC-DC converter to achieve the 5 V from our two AA batteries which gave about 3 V. This included another PCB design using some capacitors, resistors, an inductor, a diode, and the IC chip LT1073-5. Once this was all ready to go, we loaded code onto the PIC (attached on page 10) to convert the hexadecimal message to a mV reading sensed at the A/D converter on the transmitter and amazingly, it didn't work. A typical result we have grown too close to. So after many different trials and even some coding nightmares later, we actually got everything to work on a breadboard! Once connected strictly to two AA batteries, we noticed that the display revealed skewed data. Further investigation and questioning lead us to believe that the DC-DC converter may be giving some noise on the 5 V power supply to the PIC and LCD so this could be a big issue. After adding capacitors between the high line and ground, we noticed that we greatly reduced noise, but had similar results to before. Some of the other major delays we had included using the receive flag interrupt, which to this day still seems to have some errors. We have tried many solutions including stepping through our code and still are unable to get the desired result. This is not a huge deal since the handheld was not part of the initial game plan.

Code Block Diagram



Hand Held Unit



*Note: Actual circuit diagram attached on page 9

Once connected strictly to two AA batteries, we noticed that the display revealed skewed data. Further investigation and questioning lead us to believe that the DC-DC converter may be giving some noise on the 5 V power supply to the PIC and LCD so this could be a big issue. Viewing the output on the oscilloscope, we saw that it in fact was a

noisy signal, not a DC voltage like we needed. After adding capacitors between the high line and ground, we noticed that we greatly reduced noise, but still had similar results to before. Some of the other major delays we had included using the receive flag interrupt, which to this day still seems to have some errors. Again, we stepped through the code and did not seem to find anything that would be the problem. So we applied 5V and ground from the PIC board, to find that it worked correctly! Upon finding this out, we decided that it in fact was due to noise or interference caused by this converter circuit or by the proximity of all the wires inside the enclosure.

Lessons Learned

Throughout the project, we had plenty of setbacks and hang-ups that greatly hindered our progress. The first semester was a decent introduction to what we could look forward to. First off, we had designed our e-field sensor but kept blowing the MOSFETs which controlled the switching mechanism.

More research in this, and other aspects of our project could have greatly saved time and money. Many other people could have run into similar problems that we were having, and reading about their solutions could have greatly reduced our efforts.

This closely relates to time management and keeping priorities straight. Juggling between this and classes is not an easy task, especially when you may be working outside of classes as well. Sacrificing time for this or other activities is not always easy or pleasing, but this is what we chose.

Starting the second semester, we decided upon a transceiver to work into the mix so we went ahead and ordered it. We choose this first one based on the fact that we should not need a PIC processor to control every one of the transceivers we used. After more deliberation and looking into the situation, we found that indeed we would need a processor of some sort to work with these particular models. We researched further and eventually found the Xbee RF-modules.

Testing is a great part of a project, and not having an inclusive lab seemed to greatly hinder our achievements. We couldn’t really know what to expect from the field results since our calculations didn’t seem to match too close to field results.

Another major lesson came from the PCB’s and parallel wiring running in close proximity inside the enclosures. Sending wireless data is not that easy, and then needing to display that data through a series of wires can make it nearly impossible if you can’t seem to find the problem. It is just really hard to conduct an experiment when you’re not exactly sure what has changed from the control. For example, during troubleshooting you use the control, power down the working circuit, repower the

components and you don't have a consistent result, having changed nothing. This can be very frustrating and make solutions almost unobtainable.

Future Work

Our design leaves and endless amount of possible future work for this project. First off, the A/D data sent to the LCD of the handheld could be used to actually determine line voltage using a simple formula. This could use the sensed e-field voltage and distance from line to determine what the voltage on the distribution line would be.

To further improve the senor, it could be powered by solar energy. This would reduce the need to replace batteries in sensors that may be going down every 6 months. Taking it completely the rest of the way to become strictly passive would also be an improvement. Initially that was our idea, but after discouraging calculation results, we chose to spend more time on developing a model we knew we had time to finish.

We could also potentially filter the sensed signal to make sure we are only using E-field from a 60 Hz source, and then rectify the sensed signal to give the transceiver more consistent data to send down line regarding the transmission line.

Technical Troubleshooting

LCD does not display anything:

- Press the RESET button
- Is the device on?
- Check the batteries
- Make sure the connectors of the LCD are properly arranged
- Make sure the connectors on the PIC board are properly arranged
- Adjust the LCD Potentiometer (adjusts the brightness of the screen)

LCD does not display readings:

- Make sure that you are within the coverage area of the transmitter
- Press the RESET button
- RESTART the device
- If it still does not display the readings, check for the batteries on the SENSOR unit
- Check the data cable, that runs from the transceiver to the PIC board
- Check the connectors on both the boards
- The LED on RX pin turns green while receiving, if this does not occur, there is some major problem with the transceivers
- Update firmware of the transceivers

- You can also check the Transceivers on the programming board, by displaying the data on the X-CTU software or HyperTerminal
- With more technical problems related to the transceivers, refer the Xbee manual.

No data is received at the substation:

- Is the receiver powered?
- Is it receiving data (check for the pulsating GREEN lights)
- Is the receiver connected to the computer?
- Is the baud rate of the COM port set to 9600?
- If you are using Hyper Terminal, make sure that it is in CALL mode
- Make sure that the RF-Module perfectly sits in the interface board
- Is still it does not work, try restarting the entire system
- Check with the computer manual for the COM port & Hyper Terminal setting
- Update firmware of the transceivers
- If it still does not display the readings, check for the batteries on the SENSOR unit
- The LED on programming board turns green while receiving, if this does not occur, there is some major problem with the transceivers
- You can also check the Transceivers on the X-CTU software's command terminal
- With more technical problems related to the transceivers, refer the Xbee manual

RF-Module configurations

Router: transceiver that is attached to the sensing device

FIRMWARE: ZNET 2.5 Router/End Device API version 1241	
PAN ID	716
NI	ROUTER1
DH	0
DL	FFFF
SH	13A200
SL	XXX-XXX-XX
D1	2
IR	1388

D1=2 this is the ADC input setting. By setting IR=1388, we have set a sample rate of 5 seconds. The module will sample the D1 pin every 5 seconds and create and send an API frame. The DH and DL commands determine the destination address of the IO samples. Here the DH and DL are set to broadcast.

Coordinator: transceiver that is attached to the substation computer or handheld

FIRMWARE: ZNET 2.5 COORDINATOR API version 1141	
PAN ID	716
NI	COODINATOR1
DH	0
DL	FFFF
SH	13A200
SL	XXX-XXX-XX

NOTE: only devices running API firmware can send IO data samples out their UART. Devices running AT firmware will discard received IO data samples. This is the reason the coordinator is loaded with API firmware.

NOTE: Analog samples are returned as 10-bit values. The analog reading is scaled such that 0x0000 represents 0V, and 0x3FF = 1.2V. (The analog inputs on the module cannot read more than 1.2V.) Values for the "Output Volts" column are derived by converting the Hex values back to Volts using the following formula. Output Volts= (Hex Output/0x3FF)*1.2V (rounded to 2 decimal points).

THE API FRAME

Below is an example of an API frame sent out the receiving modules UART

7E 00 12 92 00 13 A2 00 40 0A 3D BF 66 BA 01 01 00 00 02 03 FF 4C

Where the UART API data stream can be broken down as:

7E	Start Delimiter
00 12	Length Bytes
92	API Identifier Value
00 13 A2 00 40 0A 3D BF	64-bit Address
66 BA	16-bit Address
01	Receive Options
01	Number of sample sets included in the payload
00 00	Digital Channel Mask
02	Bitmask field that indicates which digital IO lines on the remote have sampling enabled
03 FF	2 byte value indicating the A/D measurement of input
4C	Checksum

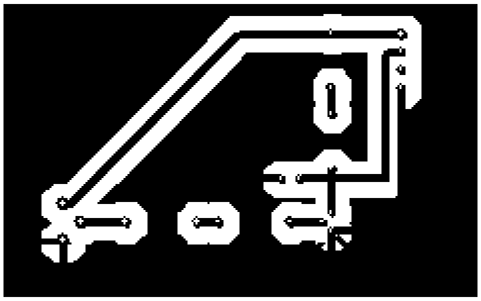
Final Budget Spent

Since our sensing apparatus requires only basic components like mosfet, resistors, diodes and LEDs, which are provided by the university, we did not dip as far into our project's expected budget as we initially planned on. We also planned on sending out our PCB's to be done professionally, but we actually had time and focused on building those in house as well, saving more money than we could have expected.

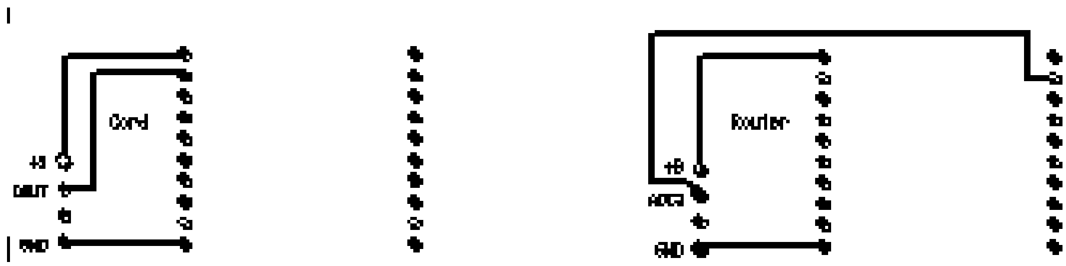
Part Description	*Qty.*	*Cost ($)*	Expected Cost ($)
Voltage Sensor			
AAx2 and Battery mount	1	3.00 ea.	-
Transceiver (1st Try)	2	18.00 ea.	36.00
Transceiver	1	27.00 ea.	27.00
Antenna	3	5.00 ea.	15.00
Housing	1	Free	-
Receivers			
Substation PC			
•Development board	1	60.00 ea.	-
•Transceiver	1	27.00 ea.	27.00
Handheld Receiver			
•Housing	1	4.00 ea.	4.00
•Transceiver	1	27.00 ea.	27.00
•LCD	1	10.00 ea.	-
•AAx2 holder	1	3.00 ea.	-
•PIC Microcontroller	1	12.00 ea.	-
•DC/DC LT1073	1	4.00 ea.	4.00
Actual Total			**140.00**
Expected Total			**358.00**
Under Bucket by $218.00			

Appendix:

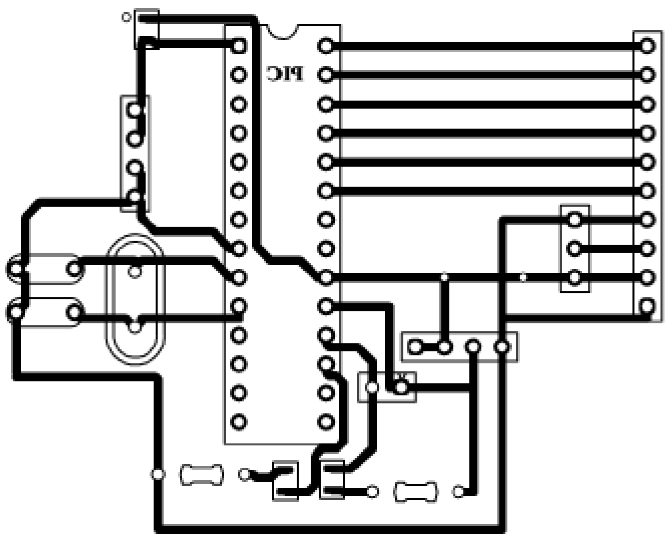
Sensing Circuit PCB



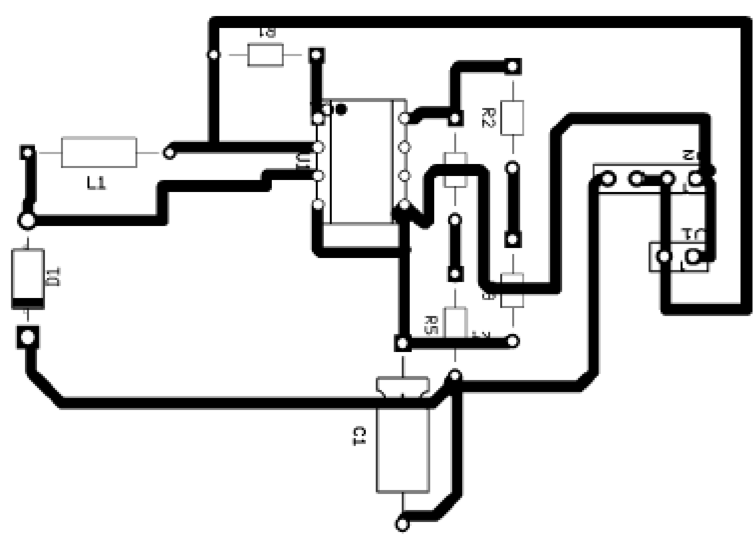
Transceiver PCBs



PIC components PCB

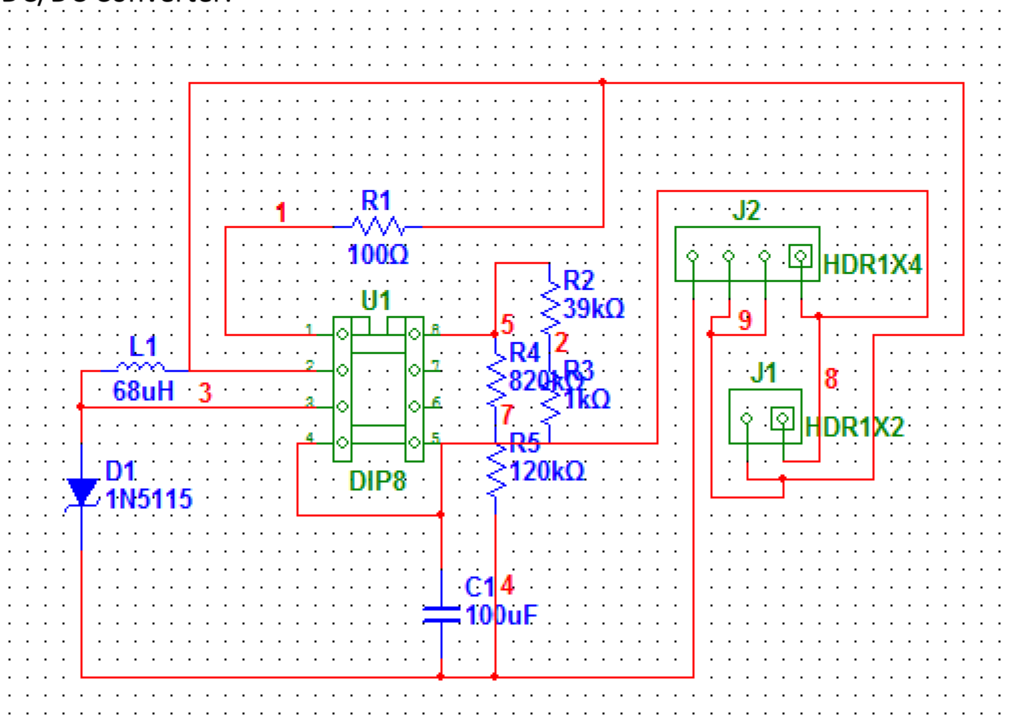


DC/DC Converter PCB

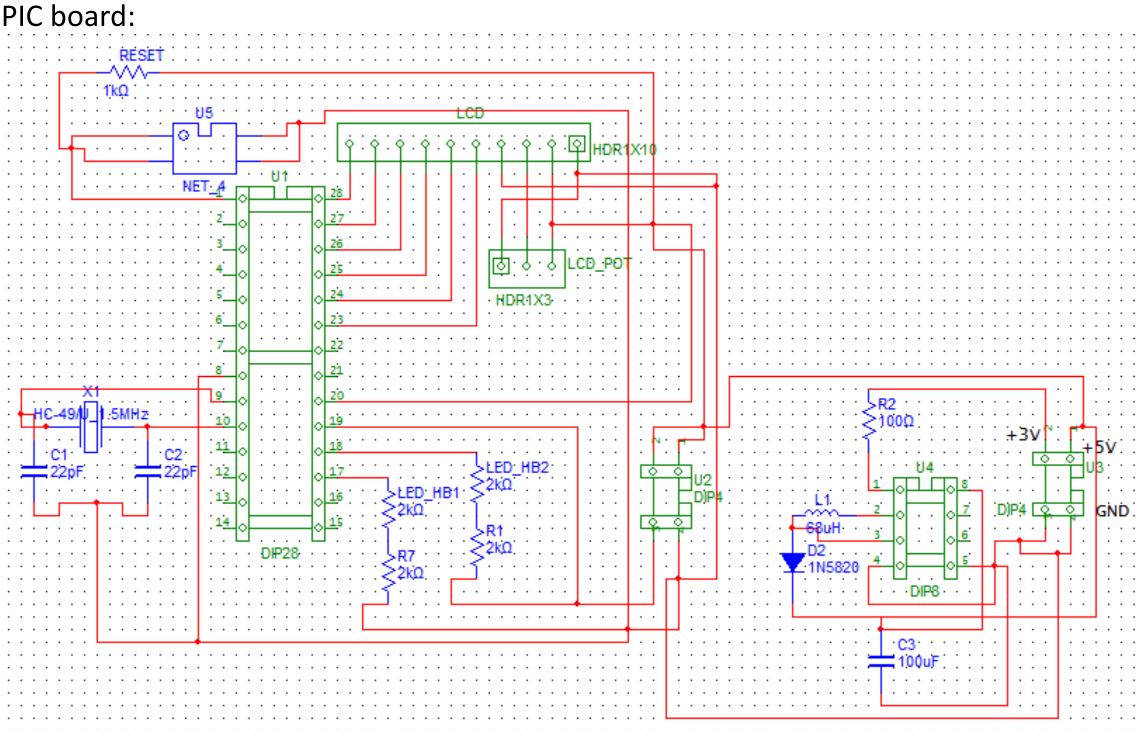


Circuit Diagram:

DC/DC Converter:



PIC board:



Microcontroller Code

```
// ---  SD 0716 -------------------
//
//   April 30, 2008:
// Global Variables

bank1 unsigned char MSG[10];    // sci message coming in
bank1 unsigned char MSG_LENGTH;  // length of message
bank1 unsigned char TEMP;       // temp variable
bank1 unsigned char N;          // temp length of message
bank1 unsigned char FLAG;       // 1 means carriage return seen

unsigned char msg[4];
unsigned char temp1;

const unsigned char MSG0[6] = "SD0716";
const unsigned char MSG1[8] = "Voltage:";
const unsigned char MSG2[2] = "mV";

// Subroutine Declarations
#include    <pic.h>

static volatile unsigned int Timer1 @ 0x0E;
static volatile unsigned int Capture1 @ 0x15;

// Header Files
#include      "lcd_20x4.h"
#include      "function.h"
#include      "a2d.h"

// Subroutines
#include      "lcd_20x4.c"
#include      "function.c"
#include      "bootloader.c"
#include      "a2d.c"

void LCD_Out(unsigned int DATA)
{
  unsigned char A[4], i;
  for (i=0; i<3; i++) {
    A[i] = DATA % 10;
    DATA = DATA / 10;
    }
//          lcd_write(ascii(A[3]));
            lcd_write(ascii(A[2]));
            lcd_write(ascii(A[1]));
            lcd_write(ascii(A[0]));
            lcd_write(' ');

            DATA = 0;
  }
```

```
// Main Routine
void main(void)
{           unsigned char i;
            unsigned int A2D;
            unsigned char A[5];
            unsigned int data;
            float dataout;

            TRISB  = 0x00;
            TRISC  = 0x00;
            TRISA  = 0x00;
            ADCON1 = 6;
            PORTC = 0;
            PORTB = 0;
            PORTA = 0;
            FLAG = 0;
            Wait_ms(100);
            lcd_init();             // initialize the LCD
            Wait_ms(100);
            lcd_move(0,0);
            // Initialize Serial Port
            TRISC = TRISC | 0xC0;
            TXSTA = 0x22;         // 8-bit no parity
            RCSTA = 0x90;         // continuous receive
            TXIE  = 0;          // no interrupt on xmit
            RCIE  = 1;          // no interrupt on receive
            BRGH  = 1;
            SPBRG = 129;          // 19200 baud @ 20MHz = 64
            CCP1CON = 0x0A;
            CCP1IE = 1;
            TRISC2 = 0;
            A2D_Init();
            GIE    = 1;
(           lcd_move(0,8);
            for (i=0; i<6; i++) lcd_write(MSG0[i]);
                        lcd_move(1,0);
            for (i=0; i<8; i++) lcd_write(MSG1[i]);
                        lcd_move(1,14);
            for (i=0; i<2; i++) lcd_write(MSG2[i]);
                        lcd_move(1,9);
            while(1)
            {
            if(RCIF)
            {
            TEMP = RCREG;
                       if(N==19)
                        {
                        data = TEMP<<8;
                        }
                        if(N==20)
                        {
                        data = data + TEMP;
                        dataout = data;
                        dataout = dataout/1023*1200;
                        data = (int)dataout;
                        LCD_Out(data);
                        }
            N++;
            RCIF = 0;
            }
   }
}
```

Complete Parts List

Component	**Part Number**	**Retail Price**	**Our Cost**
Transceiver x3	XB24-BSIT-004	27.00 ea.	81.00
Transceiver antenna x3	XST-AN019a	5.00 ea.	15.00
LCD Display x1	LM044L	10.00 ea.	0.00
Battery Boxes x2	AA-2 Battery Box	3.00 ea.	0.00
PIC Microcontroller x1	16F876A	12.00 ea.	0.00
Crystal x1	20 MHz Crystal	1.00 ea.	0.00
DC/DC Converter x1	LT1073 CN8	4.00 ea.	4.00
Sensor Enclosure	OD33-2.0	10.00 ea.	0.00
Handheld Enclosure	Radio Shack (270-1805)	4.00 ea.	4.00
Various resistors and pots			
Various capacitors			
Various diodes and LEDs			
Various inductors			
Total			$104.00

PIC Processor

MICROCHIP

PIC16F87X

28/40-pin 8-Bit CMOS FLASH Microcontrollers

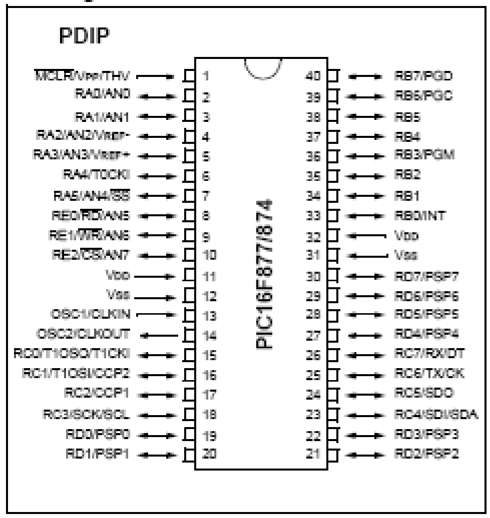
Devices Included in this Data Sheet:

- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High-performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
  Up to 368 x 8 bytes of Data Memory (RAM)
  Up to 256 x 8 bytes of EEPROM data memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code-protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low-power, high-speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial and Industrial temperature ranges
- Low-power consumption:
  - < 2 mA typical @ 5V, 4 MHz
  - 20 µA typical @ 3V, 32 kHz
  - < 1 µA typical standby current

Pin Diagram



Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master Mode) and I^{2}C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

4x20 LCD

■ ABSOLUTE MAXIMUM RATINGS

Item	Symbol	Standard Value			Unit
		Min.	Typ.	Max.	
Supply Voltage for Logic	V_{DD}-	0	—	7.0	V
Supply Voltage for LCD Driver	V_{DD}-V_{EE}	—	—	13.5	V
Input Voltage	V_I	V_{ss}	—	V_{DD}	V
Operature Temp.	Topr	0	—	50	°C
Storage Temp.	Tstg	-20	—	70	°C

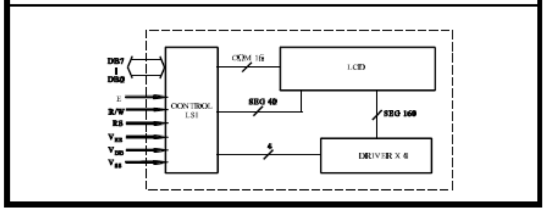
■ ELECTRICAL CHARACTERISTICS (REFLECTIVE TYPE)

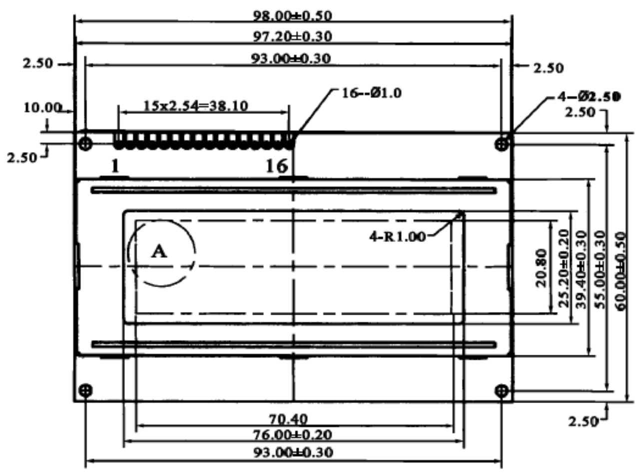
Item	Symbol	Test Condition	Standard Value			Unit
			Min.	Typ.	Max.	
Input "High" Voltage	V_{IH}	—	2.2	—	V_{EE}	V
Input "Low" Voltage	V_{IL}	—	—	—	0.6	V
Output "High" Voltage	V_{OH}	I_{OH}=0.2mA	2.2	—	—	V
Output "Low" Voltage	V_{OL}	I_{OL}=1.2mA	—	—	0.4	V
Supply Current	I_{DD}	V_{DD}=5.0A	—	2.5	4.0	mA

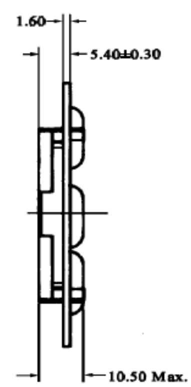
■ PIN FUNCTIONS

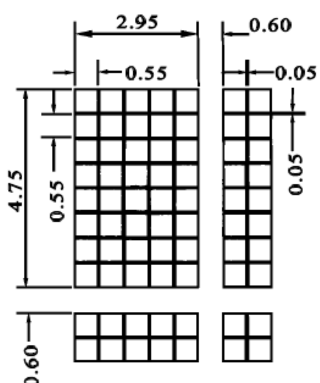
No	Symbol	Function	No	Symbol	Function
1	V_{SS}	GND, 0V	10	DB3	Data Bus
2	V_{DD}	+5V	11	DB4	—
3	V_{EE}	for LCD Drive	12	DB5	—
4	RS	Function Select	13	DB6	—
5	R/W	Read/Write	14	DB7	—
6	E	Enable Signal	15	LEDA	LED Power Supply
7-9	DB0-DB2	Data Bus Line	16	LEDA	

■ BLOCK DIAGRAM









A BLOCK

LT1073

Micropower DC/DC Converter Adjustable and Fixed 5V, 12V

FEATURES

- No Design Required
- Operates at Supply Voltages from 1V to 30V
- Consumes Only 95µA Supply Current
- Works in Step-Up or Step-Down Mode
- Only Three External Off-the-Shelf Components Required
- Low-Battery Detector Comparator On-Chip
- User-Adjustable Current Limit
- Internal 1A Power Switch
- Fixed or Adjustable Output Voltage Versions
- Space-Saving 8-Pin PDIP or SO-8 Package

APPLICATIONS

- Pagers
- Cameras
- Single-Cell to 5V Converters
- Battery Backup Supplies
- Laptop and Palmtop Computers
- Cellular Telephones
- Portable Instruments
- 4mA to 20mA Loop Powered Instruments
- Hand-Held Inventory Computers
- Battery-Powered α, β, and γ Particle Detectors

DESCRIPTION

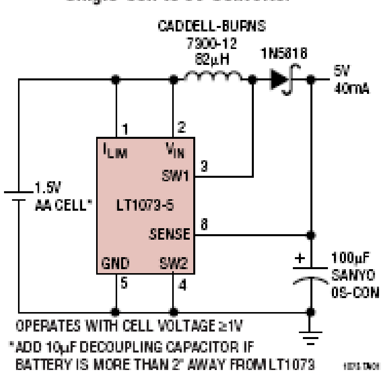
The LT®1073 is a versatile micropower DC/DC converter. The device requires only three external components to deliver a fixed output of 5V or 12V. The very low minimum supply voltage of 1V allows the use of the LT1073 in applications where the primary power source is a single cell. An on-chip auxiliary gain block can function as a low-battery detector or linear post-regulator.

Average current drain of the LT1073-5 used as shown in the Typical Application circuit below is just 135µA unloaded, making it ideal for applications where long battery life is important. The circuit shown can deliver 5V at 40mA from an input as low as 1.25V and 5V at 10mA from a 1V input.

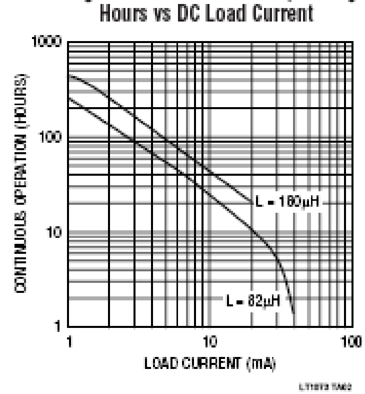
The device can easily be configured as a step-up or step-down converter, although for most step-down applications or input sources greater than 3V, the LT1173 is recommended. Switch current limiting is user-adjustable by adding a single external resistor. Unique reverse-battery protection circuitry limits reverse current to safe, nondestructive levels at reverse supply voltages up to 1.6V.

TYPICAL APPLICATION

Single-Cell to 5V Converter



Single Alkaline "AA" Cell Operating Hours vs DC Load Current



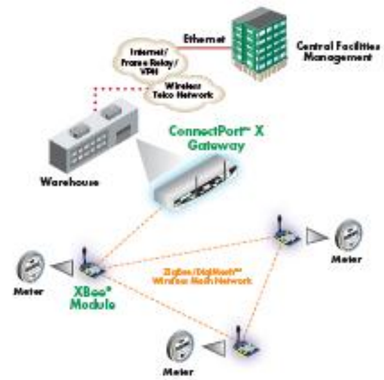
XBee Transceiver

Product Datasheet

XBee® ZigBee®/Mesh RF Modules

Embedded RF Modules for OEMs

Providing critical end-point connectivity to Digi's Drop-in Networking product family, XBee ZigBee/Mesh RF modules are low-cost and easy to deploy.



Features/Benefits

- ZigBee/mesh and proprietary peer-to-peer mesh topologies
- 2.4 GHz for worldwide deployment
- Fully interoperable with other Digi Drop-in Networking products, including gateways, device adapters and extenders
- Common XBee footprint for a variety of RF modules
- Low-power sleep modes
- Multiple antenna options
- Industrial temperature rating (-40° C to 85° C)
- Low-power and long-range variants available

Overview

XBee Product Family

The XBee family of embedded RF modules provides OEMs with a common footprint shared by multiple platforms, including multipoint and ZigBee/mesh topologies, and both 2.4 GHz and 900 MHz solutions. OEMs deploying the XBee can substitute one XBee for another, depending upon dynamic application needs, with minimal development, reduced risk and shorter time-to-market.

Why XBee ZigBee/Mesh RF Modules?

For applications where robust mesh networking topologies are preferred, XBee ZigBee/mesh OEM RF modules provide developers with both ZigBee mesh and the soon-to-be-released proprietary DigiMesh™ topologies. These networks allow devices to harness the entire network of RF modules to effectively extend range beyond that of a single module, and create a more stable and reliable network. Employing dynamic self-healing, self-discovery functionality for reliable communications, XBee ZigBee/mesh OEM RF modules make mesh networking simple and easy to deploy.

Drop-in Networking End-Point Connectivity

XBee OEM RF modules are part of Digi's Drop-in Networking family of end-to-end connectivity solutions. By seamlessly interfacing with compatible gateways, device adapters and extenders, the XBee embedded RF modules provide developers with true beyond-the-horizon connectivity.

Mosfet – 2N7000

FAIRCHILD SEMICONDUCTOR ™

November 1995

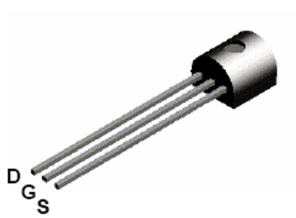
2N7000 / 2N7002 / NDS7002A
N-Channel Enhancement Mode Field Effect Transistor

General Description

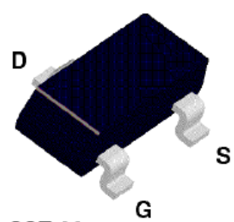
These N-Channel enhancement mode field effect transistors are produced using Fairchild's proprietary, high cell density, DMOS technology. These products have been designed to minimize on-state resistance while provide rugged, reliable, and fast switching performance. They can be used in most applications requiring up to 400mA DC and can deliver pulsed currents up to 2A. These products are particularly suited for low voltage, low current applications such as small servo motor control, power MOSFET gate drivers, and other switching applications.

Features

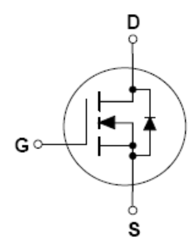
- High density cell design for low $R_{DS(ON)}$.
- Voltage controlled small signal switch.
- Rugged and reliable.
- High saturation current capability.



TO-92
2N7000



SOT-23
(TO-236AB)
2N7002/NDS7002A



Absolute Maximum Ratings T_A = 25°C unless otherwise noted

Symbol	Parameter	2N7000	2N7002	NDS7002A	Units
V_{DSS}	Drain-Source Voltage	60			V
V_{DGR}	Drain-Gate Voltage (R_{GS} ≤ 1 MΩ)	60			V
V_{GSS}	Gate-Source Voltage - Continuous	±20			V
	- Non Repetitive (tp < 50µs)	±40			
I_D	Maximum Drain Current - Continuous	200	115	280	mA
	- Pulsed	500	800	1500	
P_D	Maximum Power Dissipation	400	200	300	mW
	Derated above 25°C	3.2	1.6	2.4	mW/°C
T_J,T_{STG}	Operating and Storage Temperature Range	-55 to 150		-65 to 150	°C
T_L	Maximum Lead Temperature for Soldering Purposes, 1/16" from Case for 10 Seconds	300			°C
THERMAL CHARACTERISTICS					
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient	312.5	625	417	°C/W

Diode - 1N5819

FAIRCHILD SEMICONDUCTOR®

August 2007

1N5817 - 1N5819
Schottky Barrier Rectifier

- 1.0 A operation at TA = 90°C with no thermal runaway.
- For use in low voltage, high frequency inverters free wheeling, and polarity protection applications.

DO-41 Glass case
COLOR BAND DENOTES CATHODE

Absolute Maximum Ratings T_C=25°C unless otherwise noted

Symbol	Parameter	Value			Units
		1N5817	1N5818	1N5819	
V_{RRM}	Maximum Repetitive Reverse Voltage	20	30	40	V
$I_{F(AV)}$	Average Rectified Forward Current .375" lead length @ T_A = 90°C	1.0			A
I_{FSM}	Non-repetitive Peak Surge Current 8.3 ms Single Half-Sine Wave	25			A
T_J, T_{STG}	Operating Junction and Storage Temperature	-65 to +125			°C

Thermal Characteristics

Symbol	Parameter	Value	Units
P_D	Power Dissipation	1.25	W
$R_{\theta JA}$	Maximum Thermal Resistance, Junction to Ambient	100	°C/W
$R_{\theta JC}$	Maximum Thermal Resistance, Junction to Case	45	°C/W

* Mounted on Cu-pad Size 5mm x 5mm on PCB

Electrical Characteristics (per diode)

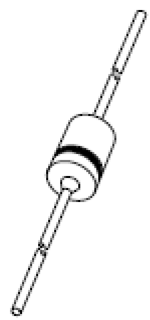
Symbol	Parameter		Value			Units
			1N5817	1N5818	1N5819	
V_F	Forward Voltage	@ 1.0 A @ 3.0 A	450 750	550 875	600 900	mV
I_R	Reverse Current @ rated V_R	T_C = 25 °C T_C = 100 °C	0.5 10			mA
C_T	Total Capacitance V_R = 4.0 V, f = 1.0 MHz		110			pF

* Pulse Test: Pulse Width=300µs, Duty Cycle=2%

Diode - 1N4148

DISCRETE SEMICONDUCTORS

DATA SHEET



1N4148; 1N4448
High-speed diodes

Product specification
Supersedes data of 2002 Jan 23

2004 Aug 10

Philips
Semiconductors

PHILIPS